FINAL REPORT
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Dynamics of Granular Materials and Particle-Laden Flows

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Rapid granular flows and particle-laden flows were studied in laboratory experiments, molecular dynamics simulations, and simulations of continuum equations. The research demonstrated that the inclusion of friction is crucial in realistic modeling of granular flows; hence extensive previous analyses and simulations by many researchers for frictionless particles must be reconsidered in the light of our work. We also made the first detailed comparison between experiment and the predictions of continuum theory for granular media (hydrodynamic equations). We found that shock waves easily form in granular flows since the speed of sound waves (pressure fluctuations) in a granular gas is small, typically 10 cm, while flow velocities are easily an order of magnitude larger. Our measurements on vertically oscillating granular layers led to the development of a novel technique for continuously separating particles of different sizes. Our study of craters formed by the impact of a projectile in a granular medium showed, surprisingly, that the time taken for a projectile to come to a rest in the granular layer is *independent* of the projectile's impact energy. Another study supported by this grant examined a vertically oscillating layer of a mixture of cornstarch and water. The discovery of stable holes in the mixture was reported widely in the popular press, e.g., *Science News* [15 May 2004], "Imaging poking a liquid to create holes that persist like the holes in Swiss cheese. Incredible as that might sound, a group of scientists has done it." Further experiments on glass spheres in an aqueous solution yielded the same holey fluid phenomenon, supporting our conjecture that such holes may occur in dense concentrations of particles in solution in industrial applications.

Ph. D. Students:

Bougie, J.	Ph.D.	now Assistant Professor at American University
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Moon, S. J.	Ph.D.	now at City Group Global Markets, Inc.
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Kharrazian, R.	Masters	Supported by our previous DOE grant and paper published during current DOE grant period
Lincoln, B.	Masters	Supported by our previous DOE grant and paper published during current DOE grant period
Mann, B. A.	Masters	Supported by our previous DOE grant and paper published during current DOE grant period
Martinez, K.	Masters	Supported by our previous DOE grant and paper published during current DOE grant period
Sailer, X.	Masters	Supported by our previous DOE grant and paper published during current DOE grant period

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Outside Collaborators (co-authors of DOE supported research papers during the current grant period):

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Publications supported by the DOE grant:

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3. M. Schröter, S. Ulrich, J. Kreft, J. B. Swift, and H. L. Swinney, "*Mechanisms in the size segregation of a binary granular mixture,*" Phys. Rev. E **74**, 011307, 1-14 (2006).

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